Lesson Overview: In this activity, students learn that smoke from wildland fires can either disperse readily or stick around, reducing visibility on the earth’s surface and making it difficult to breathe. Then they apply health guidelines regarding smoke to a very important question: Can Physical Education (PE) Class proceed with the scheduled 1-km run, or do we need to change plans?

Lesson Goal: Increase students’ understanding of smoke from wildland fires and its potential effects on human health.

Objectives:
- Students can use information about air quality and visibility to recommend measures for protecting their own respiratory health and that of others.

<table>
<thead>
<tr>
<th>Standards:</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
<th>5th</th>
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<tbody>
<tr>
<td>CCSS</td>
<td>1,2,3,4,6</td>
<td>1,2,3,4,6</td>
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<td>Language</td>
<td>1,2,6</td>
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<td>NGSS</td>
<td>Weather and Climate</td>
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<td>ESS3.B, ESS2.D</td>
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<td>Earth's Systems: Processes that Shape Earth</td>
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<td>ESS3.B</td>
<td>ESS3.C</td>
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<td>Strand 1</td>
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<td>E,F,G</td>
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Teacher Background: There’s no wildland fire without smoke, but the amount of smoke produced and the ways in which it disperses differ from one fire to another and even from one time to another on a single fire. If the smoke disperses upward rapidly, high-altitude winds will scatter it downwind, and the only noticeable result may be the beautiful, orange-tinged sunrise and sunset colors produced by particles in the air. However, if the smoke is trapped near the fire (by an inversion), it can make the air difficult to breathe and even difficult to see through. Smoke then becomes a health hazard, especially for anyone who has asthma or other respiratory illness, and for anyone engaging in strenuous exercise.

In this activity, students learn that smoke can disperse readily or be trapped by an inversion and why this matters. Then they use data on visibility to decide if smoke from a wildland fire may be hazardous to their health.
On most summer days, sunlight warms the earth’s surface each morning, and the air lying on the earth’s surface is heated too. This warming, expanding air rises, and its temperature decreases due to the expansion. If the air is dry, the temperature falls about 1°C for every 100-meter rise in altitude. As a result of this natural cooling, mountain tops tend to remain much cooler than valleys even on hot summer days. Because the air is constantly moving and mixing under these circumstances, we call it unstable.

Sometimes the sun doesn’t warm the earth’s surface very much during the day. Perhaps the earth is covered with snow that reflects the sunlight instead of absorbing its energy. Perhaps the cloud cover or the smoke layer from a fire is too dense to let sunlight through. When this happens, a warm layer of air rests on top of the cold air. The warm air traps the cold air on the earth’s surface. This is called an inversion because the normal daytime pattern (warm air on the bottom, cool air on top) is upside-down. The blanket of warm air lying on top of the cold air is called the inversion layer. During an inversion, the cold surface air is very stable. It cannot be dislodged until it is heated or stirred up by wind.

During an inversion, dust and other particulates in the air are trapped in the cold air at the earth’s surface. Inversions during wildland fires trap smoke. Sometimes it is so dense that you can’t see very far and the streetlights come on in the middle of the day. This much smoke interferes with breathing and is actually dangerous for babies and anyone with asthma or other respiratory illnesses. It is a good idea to limit aerobic activities and even to stay indoors until the air quality improves.

**NOTE:** This activity does not discuss inversions and how they form. If you are interested in presenting that information and demonstrating an inversion, see Middle School Lesson M09.

**Materials and preparation:**

- Download *E07_smoke_slides.pptx*
- Print 1 copy/student of **Handout E07-1:WhatWillWeDoWithPECClass?**

**Procedures:**

1. Ask students: What is smoke? Smoke consists of water, gases, and tiny particles of unburned and partially burned fuels. These are called **particulates** or **particulate matter**. The particulates are light enough to circulate in the atmosphere instead of settling immediately to earth, as larger particles do.

2. Project *E07_smoke_slides.pptx*. Use the handout and narrative shown at the end of this activity.
   - Slides 1-4 illustrate where smoke goes and how it can hang around for days or even weeks.
Slide 5-10 illustrate the effect of smoke on visibility. They show a single viewpoint with different amounts of smoke.

- Slide 5 explains the metric used to measure air quality: micrograms/cubic meter ($\mu g/m^3$), the weight of smoke particulates of a certain size (and smaller) in a specific volume of air. PM10 is the weight of particulates 10 micrometers across and smaller. PM2.5 is the weight of particulates 2.5 micrometers across and smaller.

- Slide 10 is a summary of slides 5-9. It shows the changes in visibility with 5 vs. 90 $\mu g/m^3$ of PM10.

3. **Ask:** How does smoke affect us? Smoke reduces visibility, as the photos showed. Smoke also makes it harder to breathe as the particles get stuck inside our lungs. The particles interfere with our ability to absorb oxygen and release carbon dioxide.

4. **Explain:** Medical experts have provided guidelines for outdoor recreation to help us protect our lungs from smoke. Give each student a copy of **Handout E07-1: What Will We Do with PE Class?**

5. **Go back to Slides 7-9.** For each photo, use the handout to decide together what to do with PE class: Are these conditions OK for a soccer match? for a 1-km run? for a basketball game? How about volleyball – indoors or outdoors? If a student has asthma, should he/she have additional restrictions?

**Assessment:** Instruct the students:

1. **Pair off.** One of you be the school nurse, the other be the Physical Education (PE) teacher. There have been some large fires in your area recently. You look out the window, and you see that the air is smoky. You can just barely see the top of a hill 4 miles away. You had planned to have your PE class do a timed 1-km run today, but now you are not sure you should do that. Talk the situation over, use the handout, and decide what to do about PE class. Make sure your plan will take care of 3 students who have asthma.

2. Together, report to the class. Answer these questions:
   - What kinds of activities does the handout recommend for the amount of smoke in the air today?
   - What will you do in PE class today and why? If you are not going to do the scheduled 1-km run, what activities will you do instead?
   - Do you have special instructions for the students who have asthma?
**Evaluation:**

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<tr>
<th>Full Credit</th>
<th>Partial Credit</th>
<th>Less than Partial Credit</th>
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<tbody>
<tr>
<td>-The student pair used information on handout to explain that visibility of four miles fits in the <strong>unhealthy</strong> health effect category.</td>
<td>-The student pair makes one or two of the following errors:</td>
<td>-The student pair did not use recommendations from handout or did not show understanding of health effects of smoke.</td>
</tr>
<tr>
<td>-The pair decided to postpone or cancel the 1-km run because it is a high-exertion activity.</td>
<td>-used the wrong health effect category or did not show understanding of health effects of smoke.</td>
<td>-The pair did not choose an appropriate activity.</td>
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<tr>
<td>-The pair chose an appropriate alternative activity*</td>
<td>-chose inappropriate activity for the health effect category chosen</td>
<td>-If they chose an outdoor activity, they did not choose an appropriate activity for asthmatic students.</td>
</tr>
<tr>
<td>-If they chose an outdoor activity, they provided an indoor alternative for students who have asthma.</td>
<td>-If the pair chose an outdoor activity, they did not provide an indoor alternative for students with asthma.</td>
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*Appropriate activities:*

- If outdoors, the activities should be low-exertion and possibly short in duration. This might be an opportunity to practice kicks and footwork in soccer, pitching/batting in softball, etc. It is difficult to assess what the handout means by “prolonged periods of time,” but a 40- to 60-minute PE class is probably acceptable. However, asthmatic students cannot participate outdoors.
- If indoors, can be high-exertion and use the whole class period, and asthmatic students can participate. However, it might be good to err on the side of caution, since indoor air can become quite polluted when outdoor smoke concentrations are high.
- A classroom lesson or activity, perhaps something related to health or diet, might be a good alternative – especially if the gym is not available.
Handout E07-1: What Will We Do with PE Class?

Decision making recommendations during wildfire season for

Outdoor Sporting Events

based on visibility and air quality

<table>
<thead>
<tr>
<th>Health Effect Category*</th>
<th>Visibility</th>
<th>Recommendation</th>
</tr>
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<tbody>
<tr>
<td>Good</td>
<td>13.4 miles and up</td>
<td>Hold outdoor sporting events as usual. Athletes with asthma should keep rescue inhalers readily available and pretreat before exercise as directed by their healthcare provider. All athletes with respiratory illness should limit outdoor activity, monitor symptoms and reduce/cease activity if symptoms arise.</td>
</tr>
<tr>
<td>Moderate/ Unhealthy for Sensitive Groups</td>
<td>5.1 to 13.3 miles</td>
<td>Consider postponing/delaying outdoor sporting events, especially high exertion activities like soccer and track and field. If possible, move athletic practices indoors. If event/practice is held, athletes with asthma or other respiratory illnesses are advised not to participate. All athletes should limit their outdoor activity for prolonged periods of time.</td>
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<tr>
<td>Unhealthy</td>
<td>2.2 to 5.0 miles</td>
<td>Consider postponing/delaying all outdoor sporting events. Move all athletic practices indoors. All athletes with asthma and other respiratory illnesses are advised to stay indoors. All others should avoid prolonged exertion outdoors.</td>
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<tr>
<td>Very Unhealthy</td>
<td>1.3 to 2.1 miles</td>
<td>Cancel all outdoor sporting events or relocate to an indoor location. Move all athletic practices indoors.</td>
</tr>
<tr>
<td>Hazardous</td>
<td>1.3 miles or less</td>
<td>Cancel all outdoor sporting events or relocate to an indoor location. Move all athletic practices indoors.</td>
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At all times, athletes experiencing respiratory symptoms should consult their personal healthcare provider.

*Visibility: How far can you see? To figure this out:
1. Face away from the sun.
2. Look for landmarks at a known distance from you.
3. If you can’t see a landmark, then you know that visibility is less than that distance.

Source: [http://www.missoulacounty.us/home/showdocument?id=5543](http://www.missoulacounty.us/home/showdocument?id=5543)
Slides and notes for E07_smoke_slides.pptx

Slide 1
We’ve measured the shape of the heat plume from small fires, and we’ve watched the smoke from our classroom experimental fires. Here are photos of smoke from wildland fires. Where does the smoke usually go? (Up, and then in the same direction as the wind. It also stays around the base of the fire where it is being produced.)

Slide 2
Smoke doesn’t just disappear into the air. Satellite photos show that it can travel a long way. Discussion: Use the 25-km scale on the left photo to figure out how wide the smoke plume is (50-75 km) and how far it has traveled (at least 300 km). Think of some towns or other landmarks that are that far away.

Slide 3
Smoke sometimes settles down near the ground and stays there for days or even weeks. This might be smoke from a fire nearby, or it could be smoke from fires hundreds of miles away.

Slide 4
Here are two contrasting views, looking eastward from St. Mary Lookout, Bitterroot National Forest, MT. Top: Summer 2013. Smoke disperses upward from a fire in the valley, then drifts northward. Bottom: Smoke has settled into the valley overnight. Now it keeps sunlight from reaching the valley floor, so the air above the smoke layer is warmer than in the valley. The smoke is trapped in the cold, heavy, dense valley air.
In the next few pictures, you can see what smoke does to visibility.

OPTIONAL INFO: What is that number at the bottom of the slide? It is a way of measuring the concentration of particulates in the air. It is read “micrograms per cubic meter of particles less than 10 micrometers in diameter.”

The farthest mountains have nearly disappeared.

Now the far mountains have completely disappeared, and the near ones are very hard to see.
The arrows show how far away the mountains and ridges are in clean air and unhealthy air.